STATENS VÄXTSKYDDSANSTALT · MEDDELANDEN 12:87

NATIONAL INSTITUTE FOR PLANT PROTECTION
CONTRIBUTIONS 12:87

Experiments with fresh-air treatment for the control of grain storage pests

Experiment med friskluftbehandling för bekämpande av skadedjur i spannmålslager

BY
ROLF MATHLEIN

Med svensk sammanfattning

With 12 Figures and 7 Tables

STOCKHOLM 1961

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Emil Kihlströms Tryckeri AB Stockholm 1961

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Introduction

It frequently happens that granaries and mills in Sweden, in which imported grain is stored, become much infested by insect pests. The most common species are *Sitophilus oryzae, Rhizopertha dominica, Oryzaephilus surinamensis* and *Laemophloeus spp.* Their more or less exotic origin and consequent rather great sensitiveness to low temperatures prevent them from becoming really acclimatized in Sweden. The winter months in unheated buildings constitute a critical period for the continued existence of the populations, and often no specimens survive. This is, however, far from general. Varying local conditions cause different degrees of exposure to cold, both as regards intensity and duration. The presence of virile survivors must therefore always be regarded as possible, and as a latent danger in the storage of grain grown in Sweden.

This has been especially noticeable in connection with the long-term storage of large quantities of grain in bulk, which occurs in Sweden. Storage for several years in deep layers, consisting of deliveries from many sources, creates a situation in which the risks of attacks by insect pests may be very great. Many cases of serious infestation are on record. Characteristic of the great significance of temperature in this connection is that infestations have usually been most marked in large stores of grain laid up during the warm months of the year; for reasons of marketing, large stores have to be laid up during those months. The frequent cases of attacks have naturally led to endeavours to store grain during the cold season, when the grain has a rather low temperature. Infestations have been much less common in such stores, but not unknown, however. That the latent threat of infestation by insect pests in such conditions is a factor that must not be neglected has been shown in connection with damage by water, which sometimes occurs in storage grain. Such water damage has, almost without exception, incited activity in and increase of insects, belonging to one or other of the species mentioned above and introduced with imported grain.

The damage due to these attacks is often considerable. In addition to the direct loss in weight by feeding and the consequent lower quality of the grain, is the heating of the grain that always follows upon attacks by the species of insects in question. The development of heat has in itself no direct adverse effect on the grain, but the climatic conditions of Sweden, with relatively high humidity and low air temperatures during the winter months, when attacks usually occur, promote condensation in the surface layer of the affected grain, and consequently the development of mould.

It has proved very difficult to develop effective measures to counteract and defeat such attacks of insects. Gas treatment can hardly ever be applied, for the premises in which such large amounts of grain are stored are not

sufficiently airtight. Further, the granaries are usually so full that there is no reserve space in which to move the grain, besides which equipment for screening the grain is not generally available on the spot.

The present paper gives an account of a method applied in Sweden during recent years, based on active cooling and airing of infested grain with the help of mobile equipment. The method may be said to imply physical control, based on the low resistance of the species of insects we are concerned with to low temperatures.

The method has been used mainly in the large State reserve stores of grain, which are administered by an organization known as SVENSK SPANNMÅLSHANDEL, EKONOMISK FÖRENING. The responsibility for and planning of these often very large-scale actions have rested upon Birger Almér, the head of the storage section of the abovementioned organization, who has worked in continuous collaboration with the author of the present paper in his capacity of official at NATIONAL INSTITUTE FOR PLANT PROTECTION. Almér has very obligingly placed the necessary labor and other resources at the disposal of the author in connection with the different tests made in the various granaries. Private enterprises engaged in grain storage and trade have also shown great interest in the further application of the method.

Construction and operation of equipment

Experiments with the introduction of fresh air into grain from above with the help of mobile equipment consisting of steel tubes and fans were begun in the middle of the 1950's in Sweden on the instigation of SVENSK SPANNMÅLSHANDEL. The equipment was patterned mainly on a Russian construction described by KOSMINA, 1956, pp. 124—126, consisting chiefly of a thick steel tube, pointed and perforated at one end, a machine for driving the tube into the grain and withdrawing it again, and an electric fan by which air was pressed into the tube and through the perforations into the grain.

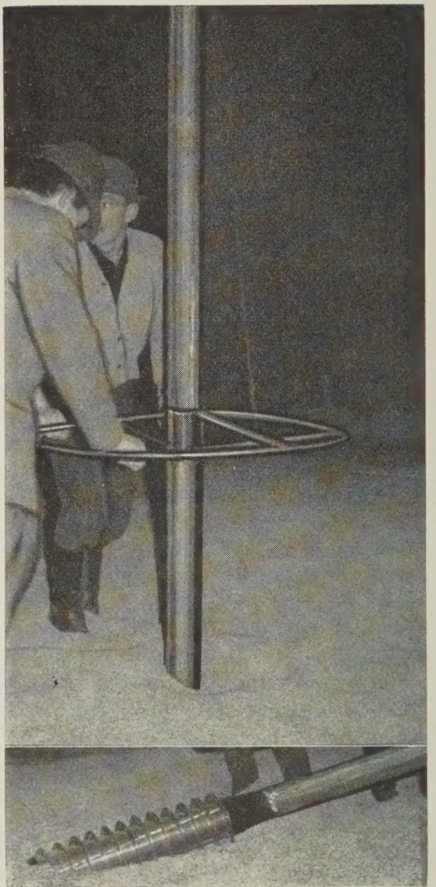

Fig. 1. Apparatus with wheel and screw-thread.
Apparat med ratt och skruv.

Equipment based on these principles, except that the tube was driven into and withdrawn from the grain manually, was first used in Sweden in March 1958; Fig. 1. It consisted of a steel tube 4 m long in one piece, the bottom end of which was fitted with a powerful screw thread of sheet metal. The tube

was screwed into the grain with the help of a wheel, adjustable at intervals along the tube by studs welded to the tube for that purpose.

Experience gained in this first treatment, reported by the author in a paper published in 1959, was very favourable as regards both cooling effect and the effect on the insect pests. The manual insertion and withdrawal of the tube required much time and labour, however, particularly as the hot zone, owing to its size, had to be treated from ten or more different positions. Three men were needed to turn the tube when it had penetrated to a depth of 2 m. The apparatus was deemed suitable for the treatment of small, single infestation sites and hot zones, and has been acquired by a number of private grain merchants in Sweden. The construction has been modified in so far as the tube consists of two sections.

It soon became obvious that large hot zones in a granary had to be treated by more than one unit of apparatus simultaneously, and in some cases at greater depths than 3 or 4 m, if the required result was to be obtained. A modified type of equipment with a machine to drive in and withdraw the tube was therefore constructed, and when it was found to function satisfactorily, a series of such units was made by SVENSK SPANNMÅLSHANDEL.

A description of the construction and function of this modified equipment follows below.

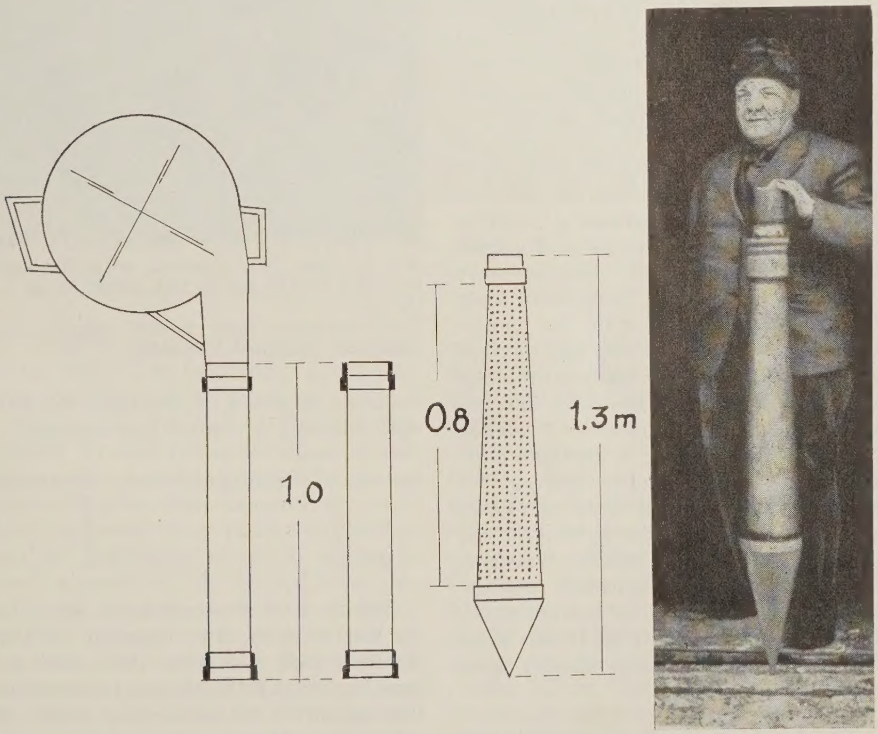

Fig. 2. Schematic picture of pipe sections. Right, cone-shaped, pointed and perforated end section, in two partially different constructions.

Schematisk bild av rörsektioner. T. h. den nedersta, konformade, tillspetsade och perforerade sektionen i två delvis olika utföranden.

The tube in the new apparatus (Fig. 2) consists of four sections capable of being connected with each other, and with the driving machine and fan fitted at one end, by spring-steel muffs. The joints are locked by bolts. The three upper sections are each 1 m long, with an exterior diameter of 102 mm and an interior diameter of 98 mm. The bottom section is 1.3 m long and terminates in a cone-shaped part; greatest diameter 165 mm, length 840 mm. The body of the cone is of sheet steel perforated with holes 13.5 mm in diameter. This body is enclosed in a case of steel sheet, 2 mm thick, perforated with numerous holes 2 mm in diameter. These two constructions are built round a steel tube running in the centre of the cone from the point of the tube to the upper end, and welded to the upper and lower part of the cone. The total surface of the perforations in the outer case of the cone is more than three times as great as the tube section.

The tubes are joined together, after which they are driven down into the grain. A sheet pile hammer, weighing ca. 50 kg (Fig. 3) was generally used to drive in the tubes. The hammer works against a dolly, weight 15.5 kg, drawn out to a cylinder for the mounting of the tubes. The hammer is kept in the correct position against the dolly with the help of a piece of flat bar iron fastened round the lower U-shaped cheeks of the hammer. A portable compressor with a working pressure of 7—8 kg per sq.cm and a force of 170 kg per stroke provides the power for the hammer. A vibration hammer weighing 75 kg driven by a portable electric motor from which power is transmitted over a flexible axle (Fig. 4) has been used with approximately equally good effect in some cases.

The working depth of a unit can, if necessary, be increased to 5—6 m by using a greater number of tube sections. The following data illustrate the time

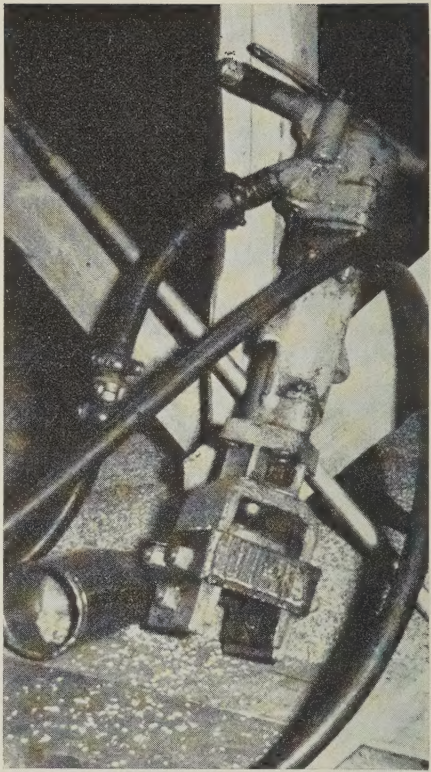

Fig. 3. Sheet pile hammer with flat bar mounted at the lower end. Dolly lying to the left.
Sponthammare med nedtill påmonterat plattjärn. Liggande t. v. städ.

required to drive in the tube sections with the help of a sheet pile hammer:

Section	1, with point and »cone»	2	seconds
»	2	6	»
»	3	8	»
»	4	14	»
»	5	19	»

Thus it took 49 seconds to drive in all the sections. The coupling of the sections took far more time, and altogether it took 10 minutes to assemble the apparatus for a working depth of rather more than 5 m.

After the sections are driven into the grain, the hammer is removed and the fan fitted (Fig. 5). The fan is driven

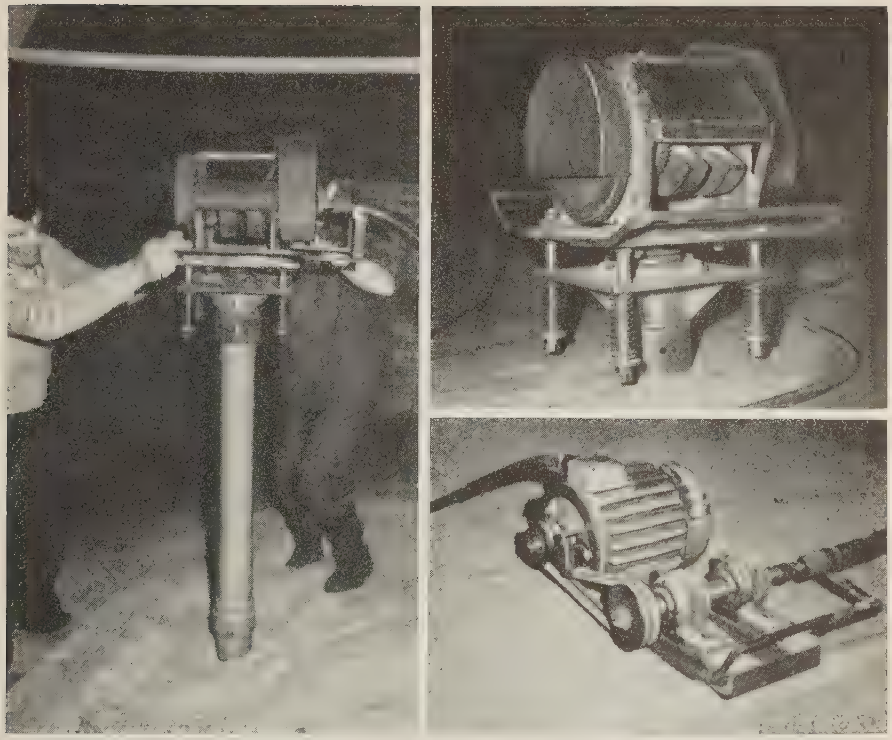

Fig. 4. Vibration hammer. Notice handles for manoeuvring and for manual assistance in driving down and drawing up the pipes. Lower right, a portable electric motor.

Vibrationshammare. Observera handtagen för manövrering samt för manuellt bistånd vid rörens neddrivning och uppdragning. T. h. nedtill en portabel elmotor.

by a direct coupled 1.5 h. p. electric motor, which, at ca. 2900 r. p. m. provides ca. 600 cu m air per hour.

Fresh air is drawn into the tube and pressed through the perforations in the lower part of the tube into the grain, where it goes first horizontally and then upwards. The radius of action may be calculated at ca. 2 m, but a weak current of air rising from the grain can be felt clearly at a distance of 4 m from the tube. According to Kosmina, the apparatus can also be used to draw air from the grain; then the tube is connected with the air intake of the fan. This operation has not been performed in Sweden, however.

The tubes have been withdrawn by block and tackle, in which operation available roof supports or transportable gear have been used. The method has been successful on the whole, although certain new technical constructions for the withdrawal of the tubes are being studied. Kosmina states that the withdrawal of the tubes can be effected by reversing the electric vibration hammer, so that it strikes upwards. The first metre or so is drawn up without any additional manual power, and the rest of the tube with a small addition of power (ca. 30 kg). The withdrawal of a tube 3.5 m long is said to take ca. 60 seconds by this method. The question, however, is whether the capacity of the vibration hammer in withdrawal is sufficient in densely packed grain at such great working depths as 4—6 m.

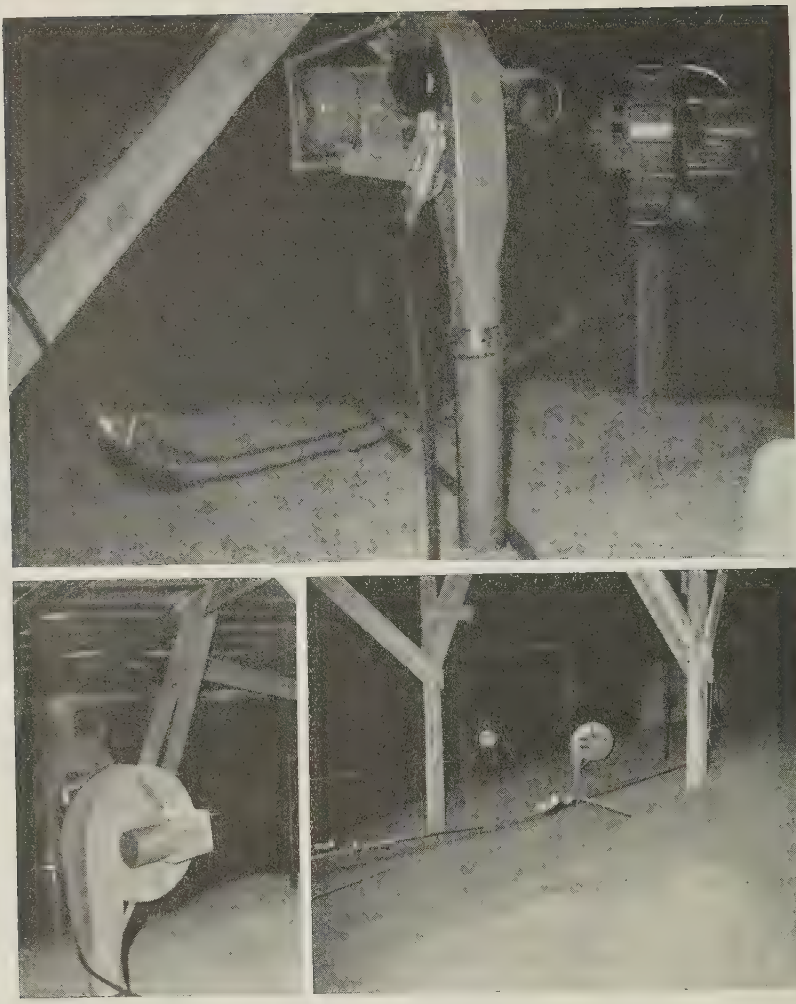

Fig. 5. Grain stores with apparatus at work.
Spannmålslager med apparater i arbete.

The results of experiments suggest that the capacity is too small.

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Seven different long-term stores of grain belonging to the State have been treated according to this method during the period 1958—60. With regard to the planning, performance and control of the results of the treatment, there was, as already mentioned, close collaboration between SVENSK SPANNMÅLSHANDEL and NATIONAL INSTITUTE FOR PLANT PROTECTION. The treatment of two stores, one of rye and the other of wheat, will be described.

Store I, rye

During the late summer of 1958, 3200 tons of rye, harvested in Sweden in 1957, were placed in a granary. The temperature of the grain was then 18—20°C, and the average water content 12.8% (range 12.2 and 13.2%).

On 2 February 1959, the granary foreman reported to the owners, Svensk Spannmålshandel, that the temperature in the rye had risen to ca. 30°C in a rather large area, and was still rising. On 10—11 February the temperature of the whole stock was studied and the reasons for the rise investigated. Fig. 6 shows a plan of the central part of the stock, where the increase in temperature occurred; the distance between the figures in the margin and between the letters is 2 m, and every point in the store can, as is seen, be defined as a point of intersection between a vertical line from a letter and a horizontal line from a figure in the margin. The figures above the horizontal lines give the temperatures on 11 February at a depth of 3 m, and at certain points within the hot zone also at 5 m (figures in parentheses); the heat was noticeable right up to the surface in the hot zone.

The hot zone, the approximate extent of which is marked by a broken line in Fig. 6, was, as already mentioned, in the central part of the store, and covered an area of 120—150 sq. m. The depth of the grain in that zone varied between 6 m in the middle, and 4 m towards the western and eastern sides where the grain was bounded by a wooden barrier, about 4 m high and ca. 1 m from the outer walls of the granary. Then the part of the grain subjected to heating was calculated at about 500 tons. The temperature in the middle of the hot zone was, as seen in the figure, between 37 and 42°C, while the average outside the hot zone was 10 to 12°C, with variations between 3°C (in the north-eastern corner, not included in the sketch) and 18°C.

It was found that the heating was caused by a great attack by *Oryzaephilus surinamensis*. In two sections of the hot zone, sharply defined in horizontal direction, each with a diameter of only ca. 50 cm, *Sitophilus granarius* and *S. oryzae* also occurred, close to two vertical wooden tubes standing on the floor and extending above the surface of the grain (intended originally to check temperatures) 10 × 10 cm square. The grain around these tubes, at points D/E-29 and D/E-40 respectively, was damp and very seriously attacked by mould. Mould was also present all over the surface area of the hot zone.

On February 17, active airing of the grain was begun with three units of equipment. After 8 days the number was increased to 5, and treatment was continued until 9 March, that is, for a period totalling 3 weeks, with the apparatus in action night and day, as a rule. Owing to interruptions in the power supply, the effective treatment lasted only 17 days.

Fig. 8 shows the location of the equipment at different points of time during treatment. It will be seen from the figure that the first phase was in the peripheral parts of the hot zone, and the front was moved successively through the hot zone, mainly in a south-westerly direction towards the open doors marked in the figure in the western wall of the granary. At every stage the tubes were first driven to the bottom of the grain. Treatment was then carried out at gradually reduced depths until a satisfactory reduction of temperature had been attained in the grain, and after that the equipment was moved for the next stage. The distance between the units of apparatus varied between 2 and 4 metres.

The temperature of the grain at different levels was checked at regular intervals three times a day, as were

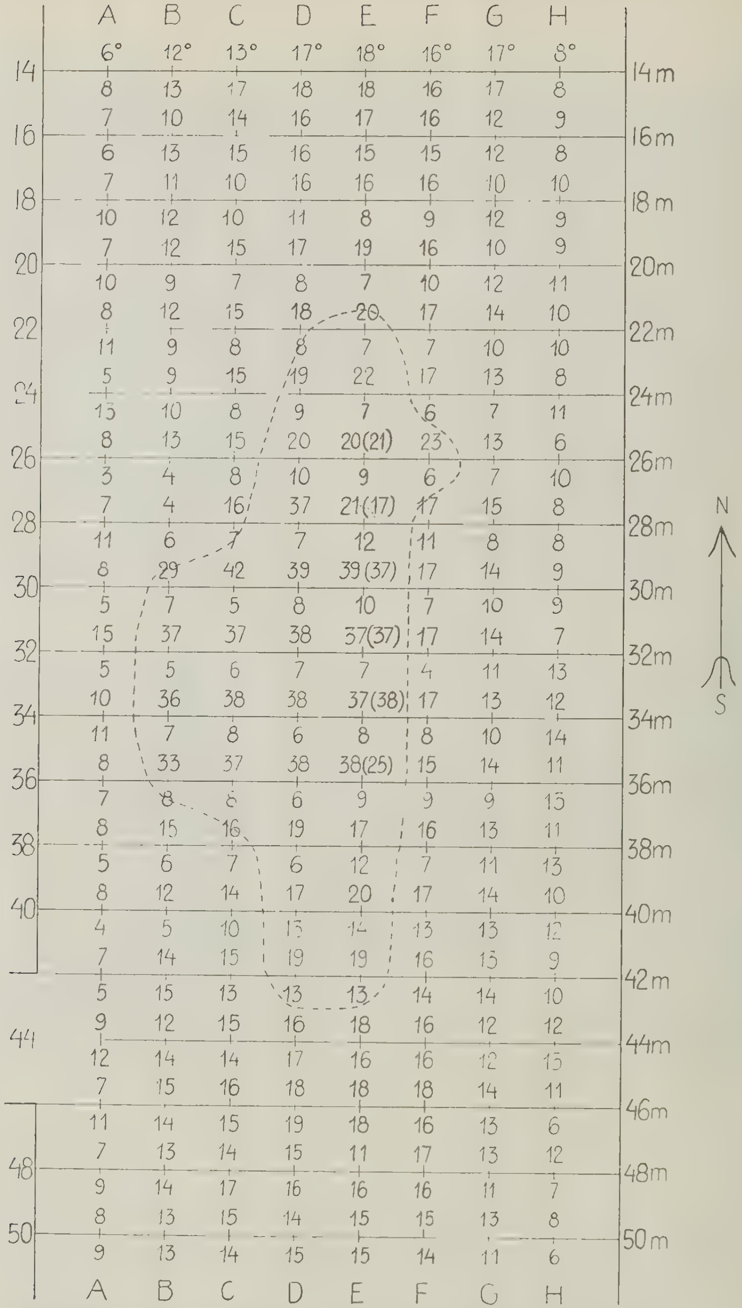

Fig. 6. Store I. Plan of store. Broken line encloses infested area and heat centre. Figures above horizontal lines = temperatures in grain 11.2.1959, before treatment, at a depth of 3 m, in brackets 5 m. Figures below lines = temperatures in grain 17.3.1959, after finished treatment, at a depth of 3 m.

Lager I. Planskiss av lagret. Streckad linje markerar området för angrepp jämte värmeutveckling. Siffrorna ovanför horisontella linjerna = temperaturer i spannmålen den 11.2.1959, före behandlingen, på 3 m djup samt, inom parenteser, 5 m djup. Siffrorna under linjerna = temperaturer i spannmålen den 17.3.1959, efter avslutad behandling, på 3 m djup.

Fig. 7. Store I. Detail view of surface of infested area, with moist and mouldly rye. Below. wooden upright, with accumulations of *Oryzaephilus surinamensis.*

Lager I. Detaljbild från det angripna områdets ytskikt, med fuktig och möglande råg. Därunder stolpe med ansamlingar av *Oryzaephilus surinamensis.*

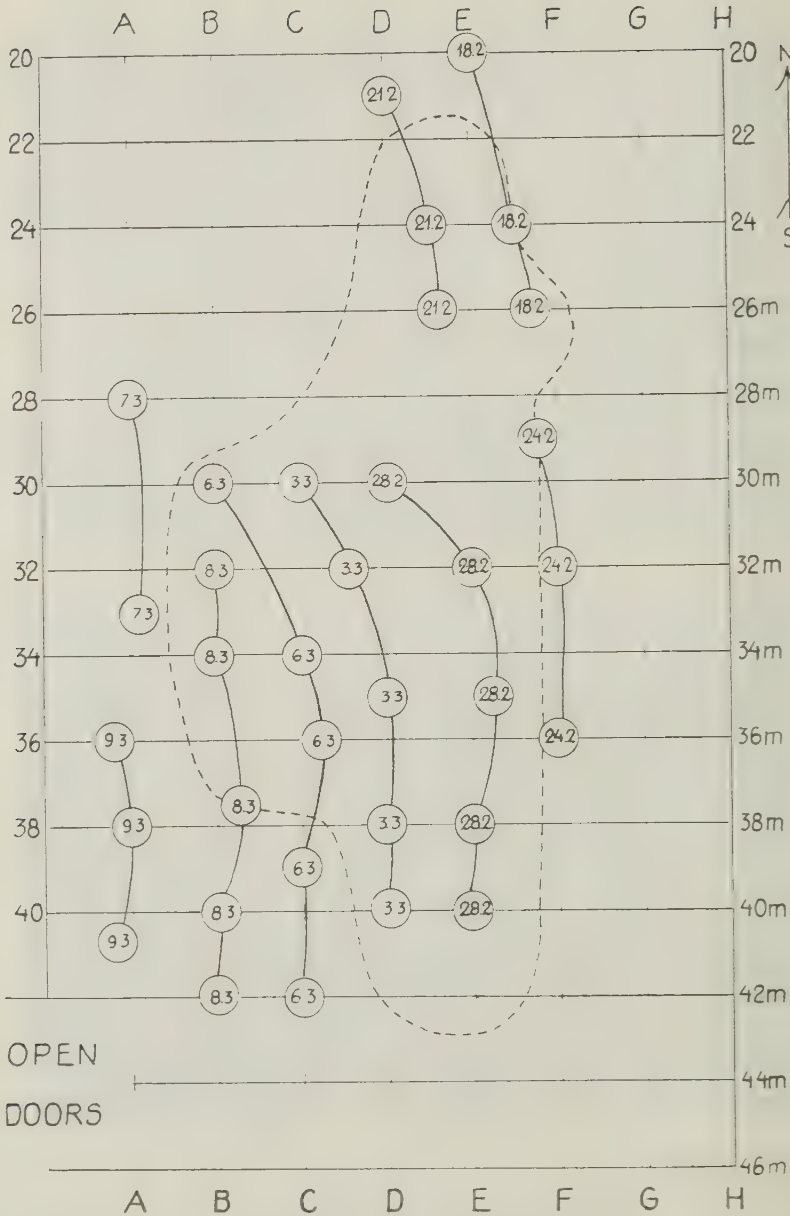

Fig. 8. Store I. Position of apparatus at different points of time during treatment period.
Lager I. Apparaternas placering vid olika tidpunkter under behandlingsperioden.

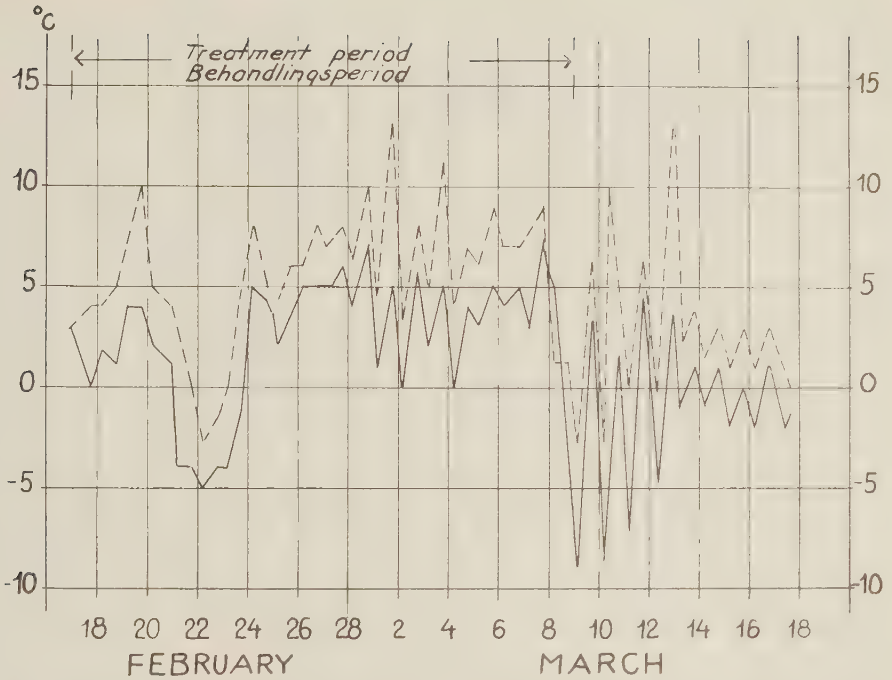

Fig. 9. Store I. Air temperature during treatment period. Unbroken line = outside, broken line = inside the granary.

Lager I. Lufttemperatur under behandlingsperioden. Heldragen linje = utanför, streckad linje = i lagerhuset.

air temperatures and relative humidity both inside and outside the granary. Samples of grain were taken at different times for the determination of the frequency of insects, water content and condition.

A very marked condensation of water appeared at the surface of the grain about a week after treatment was begun. This condensation occurred in the greater part of the hot zone, but was particularly noticeable in the vicinity of the equipment and to the west towards the outer edge of the store in the direction of the open doors. Thus it is clearly very important that the hot air driven from the grain is evacuated from the granary as quickly as possible. With this end in view, and to dry the surface of the grain, two fans were hung from the roof with the outgoing air current directed towards the open doors, and a reserve apparatus was used for point treatment at depths of only 0.5 to 1 m in those parts of the grain where condensation was particularly great. These measures were found to be quite effective, and the elimination of condensation presented no problem afterwards.

At other granaries, where separate fans were not available, the problem of condensation was solved by running the ordinary apparatus at shallow depths now and again.

As regards air temperature and relative humidity, conditions were unfavourable during the greater part of the treatment, for the weather was unusually mild for the time of the year. As will be seen from the temperature chart in Fig. 9, the temperature was

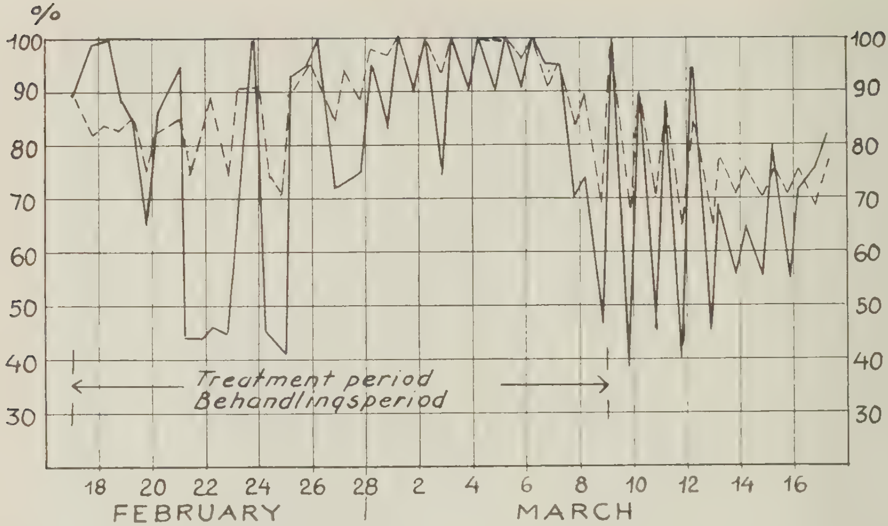

Fig. 10. Store I. Relative air humidity during treatment period. Unbroken line = outside, broken line = inside the granary.

Lager I. Relativ luftfuktighet under behandlingsperioden. Heldragen linje = utanför, streckad linje = i lagerhuset.

below freezing point on 5 out of 20 days, viz. 21–24 February, and the night of 8 March. Otherwise the outdoor temperature fluctuated from 0 to +7°C. The relative humidity, shown in Fig. 10, most often had values of between 80 and 100%, except for a few days with dry air at the end of February. The great rise in indoor temperature and humidity as a consequence of the expulsion of the heat from the grain during treatment should be observed.

In view of the circumstances mentioned, the result of the treatment, which will be reported and discussed below, must be regarded as satisfactory.

Development of temperature in grain. The temperatures at a depth of 3 m on 17 March, a week after treatment was finished, are given under the horizontal lines in Fig. 6. It will be seen that the temperatures in the store of grain were quite satisfactory, with values between 5 and 12°C in the centre of the former hot zone. Checks made at different times of the year showed that the reduction of temperature was permanent. Table 1 gives a survey of the development of temperature within the part of the grain treated; in other parts temperatures between 8 and 12°C were recorded on 1 June, and between 11 and 13°C on 1 December. The lowest layer of grain, which, owing to the construction of the pointed section of the tube was inaccessible to direct currents of air, had, after treatment, a higher temperature than the upper layer, but the table shows that the temperature sank there, too, and equilibrium gradually appeared; cf. also Fig. 11.

Fig. 11 illustrates the drop in temperature during treatment of the hot zone. It refers to point D-34, and Fig. 8 shows that on 28 February the apparatus was moved nearer the point, so that the distance to the nearest unit was ca. 2 m. With the apparatus working in the position shown, the temperature at point D-34 at a depth

Table 1. Store I. Development of temperature at different depths in infested grain. Greatest depths stated = close to floor.

Tabell 1. Lager I. Temperaturutvecklingen på olika djup i den angripna spannmålen. Största angivna djupen = invid botten.

Date *Dag*	C-32				B-34				C-34				C-36			D-41			
	1 m	3 m	4 m	6 m	1 m	2 m	3 m	4 m	1 m	2 m	3 m	4 m	1 m	3 m	5 m	1 m	2 m	3 m	5 m
Feb. 11.	—	37°	—	—	—	—	36°	—	—	—	38°	—	—	37°	—	—	—	18°	—
March 17.	—	6	—	—	—	—	7	—	—	—	8	—	—	8	—	—	—	13	—
April 3.	7	7	6	13	6	6	8	13	6	8	9	11	6	8	17	9	12	13	13
June 1.	16	7	7	11	13	8	9	11	12	8	8	11	8	9	12	15[a]	13	13	13
July 29.	15	8	10	10	11	10	10	10	12	—	10	11	11	11	11	15[a]	13	12	12
Sept. 4.	14	10	11	11	13	10	—	11	14	11	11	11	15	12	12	19[a]	19	15	13
25.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12	11	10	12
Dec. 1.	—	12	—	—	--	—	12	—	—	—	12	—	—	13	—	—	—	13	

a Close to point D/E-40, a new heating spot appeared in September. Treated with cooling-apparatus 21.9.—25.9; cf. p. 115.

Invid punkt D/E-40 uppkom en ny, begränsad värmehärd i september. Behandlades 21.9.—25.9.; jfr sid. 115.

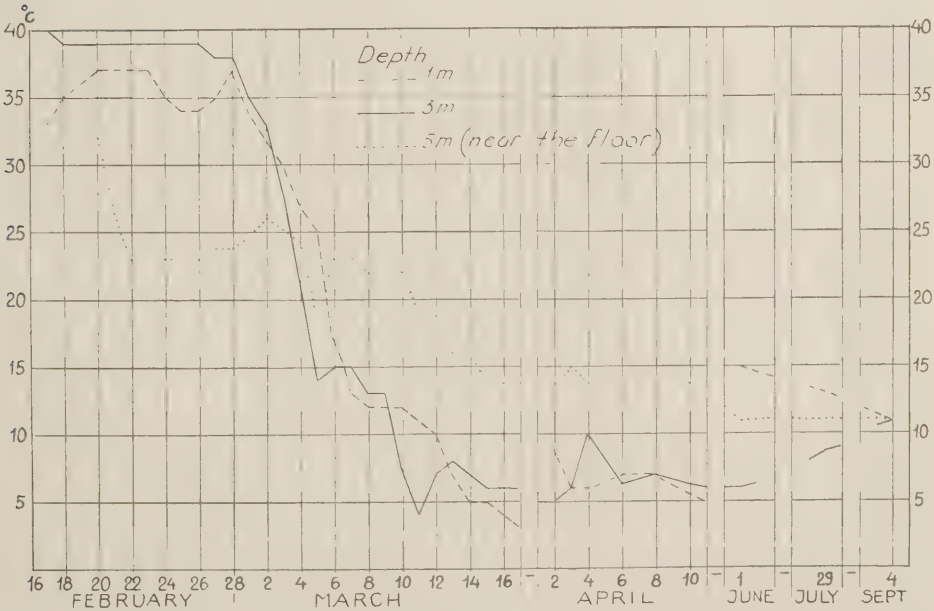

Fig. 11. Store I. Fall, and subsequent stabilization, of temperature in grain at point D-34. Treatment beginning 28.2.; cf. Fig. 8.

Lager I. Temperaturens nedgång och efterföljande stabilisering i punkt D-34. Behandlingen påbörjad 28.2.; jfr fig. 8.

of 3 m fell from 38 -39°C to 14°C in 5 days, and to 4°C after 6 more days, after which the temperature was stabilized at 6—7°C. It will be seen from Fig. 9 that the outdoor temperature never fell below 0°C during the early days of this period of treatment, but was down to —9°C sometimes during the last 3 days. (The report of Store II shows that a much more rapid reduction of temperature can be obtained with lower outdoor temperatures; cf. p. 119).

As was to be expected, there was a great temporary rise in temperature in the uninfested grain in the immediate vicinity of the hot zone in conjunction with the expulsion of the hot air. At point A-30, for example, the temperature at a depth of 3 m rose from 8 to 40°C in two days at the beginning of March. It remained at 35—40°C for three days, but then fell in one day to ca. 12°C, and in further two days to 3—4°C, and then became stable at 7°C.

Water content of grain. The results of the analyses have been brought together in Table 2. As mentioned earlier, the average water content of the rye when it was brought to the granary was 12.8%.

Table 2. Store I. Water content of grain.

Tabell 2. Lager I. Spannmålens vattenhalt.

Depth *Djup*	Place; cf. Fig. 6 *Plats; se fig. 6*	Date of sampling *Dag för provtagning*			
		17.2.	5.3.	9.3.	2.6.
Surface *Ytan*	D/E-20	12%	—	15%	12%
	C/D-30	—	—	14	12
	C/D-34	16	—	17	12.5
	A-35/36	—	—	21.5	12.5
	E-44	—	—	—	12
0.5 m	D-24	—	—	13	—
	C/D-30	—	—	12.5	11.5
	B-34	—	—	11.5	—
	C/D-34	—	—	12	—
	E-34	—	—	11.5	—
	D-36	—	—	—	11.5
	A-38	—	—	12.5	—
	C/E-38	—	—	11.5	—
	D-42	—	—	12.5	—
	D-46	—	—	12	11
1.5—2 m	D-18	—	—	—	12
	D-24	—	—	12	—
	C/D-30	—	12	11.5	11
	B/C-34	—	—	11.5	—
	C/D-34	11.5	12.5	12	—
	E-34	—	—	11.5	—
	D-36	—	—	—	10
	A-38	—	—	12.5	—
	B-38	—	11	—	—
	C/E-38	—	—	11.5	—
	D-42	—	—	12.5	—
	D-46	—	—	11.5	12

The water content was 16% in the surface layer of the hot zone before treatment was commenced, and as a consequence of condensation in conjunction with treatment it remained at this high level until treatment was finished. The high water content — 21% — in the zone A-35/36 at the end of treatment was due to the contact of the hot air expelled from the grain and the cold outside air, then —8 to —9°C, close to the doors. The surface layer dried gradually, however, and on 2 June the water content everywhere was 12—12½%.

At depths of 0.5 m and more, the water content remained on an average 11 to 12% both in the former hot zone and other parts of the store, in spite of less favourable weather conditions from the point of view of humidity during the treatment period. The high water-bearing ability of the hot air expelled from the grain was clearly able to counteract a rise in the water content of the grain in conjunction with the introduction of fresh air of comparatively high humidity.

Effect on insects. Table 3 gives the frequency of living and dead insects *(O. surinamensis)* per kg rye in the infested zone before treatment, and at different dates after treatment was ended.

Samples taken show that insects were as a rule most numerous in the layer from the surface to a depth of 0.5 m, but at certain points in the hot zones they occurred right down to the bottom layer of the grain. The low frequency or complete lack of insects in samples taken at depths of from 1 to 1.5 m before treatment was begun on 17 February was clearly due to the excessively high temperature, ca. 40°C, in this layer.

No significant invasion of other parts of the store by insects from the hot zone seemed to have taken place, and no such invasion could be expected as long as the temperature of the store remained at the low level indicated in Fig. 6.

The table shows that the frequency of living insects in the grain was about the same at the end of treatment at the beginning of March and in samples taken in April as before treatment was begun. It will be seen, too, that *larvae* were completely lacking in samples taken in the middle of April and in June and July; 52 samples were taken on 2 June, and 27 on 29 July, and all proved to be quite free from larvae. Thus the reduction of temperature, in spite of unfavourable weather conditions, was sufficient to check breeding in *O. surinamensis* almost completely. The dependence of this species on temperature should be elucidated in this connection. Studies made by Howe, 1956, show that the optimum temperature for *O. surinamensis* is between 30 and 35°C. A permanent reduction of temperature to 20°C is critical for the continued existence of the species, for then the death rate of eggs and larvae exceeds 50%, while in optimum temperatures it is ca. 10%. At 17.5°C or lower, no eggs are hatched. A small percentage of the larvae are, it is true, capable of development, and may even reach the pupal stage at 17.5°C, but the death rate in the pupal stage is 100%. On the basis of these data, it may be presumed that a total extermination of *O. surinamensis* will gradually occur in surroundings, for example storage-grain, in which the temperature does not exceed 17.5°C. On the other hand, a considerable time may elapse before such extermination is complete. Adults of the species can live for a considerable time even in temperatures much below the minimum required for breeding. It has been shown by the author, 1961, that *O. surinamensis* is able to survive a winter in storage-grain with a temperature of 8 ± 1°C. Laboratory experiments, reported in the same paper, have shown that adults can live

Table 3. Store I. Number, per kg of rye, of adults and larvae of Oryzaephilus surinamensis in samples from heat centre of store.

Tabell 3. Lager I. Antal skalbaggar och larver av Oryzaephilus surinamensis per kg råg i prov från värmehärden.

Date of sampling *Provtagnings-dag*	Depth, metres *Djup, meter*	Section C-30			Section D-34		
		living adults and larvae *levande skalb. och larver*	dead adults *döda skalb.*	frequency of larvae *larv-frekvens*	living adults and larvae *levande skalb. och larver*	dead adults *döda skalb.*	frequency of larvae *larv-frekvens*
17.2.	surface *(ytan)*				192	53	***
	0.2	485	188	**	90	33	***
	0.5	51	33	**	68	57	*
	1.0	5	10	**	0	0	—
	1.5	5	10	—	0	0	—
5.3.	0.5	72	45	**	176	57	*
	1.5	80	17	*	15	15	**
9.3.	surface	98	174	*	326	209	**
	0.2	236	144	*	929	1 040	*
	0.5	172		*			
	2.0	0		—	0	0	—
	2.9				28	43	—
	3.9				43	486	*
	4.9				685	100	**
16.3.	surface				284	62	**
	0.2	51	63	*	69	79	**
	0.5	71	37	*	96	42	*
	1.0	59	24	*	36	52	—
	1.5	27	10	*	26	17	*
3.4.	surface				36	59	*
	0.2				58	126	—
	0.5	23	38	*	83	159	—
	1.0	26	43	*	41	30	—
	1.5	57	59	*	27	27	—
13.4.	0.5.	0	25	—	0	52	—
2.6.	surface	0	127	—	0	107	—
	0.5	8	140	—	0	78	—
	1,0	0	3	—	2	8	—
	1.5	0	18	—	0	30	—
	3.0	14	128	—	50	183	—
29.7.	0.2	0	102	—	0	[1] 1 000	—
	0.5	1	69	—	0	[1] 1 000	—
	1.0	3	72	—	5	[1] 2 000	—
	1.5	12	64	—	3	[1] 500	—

[1] approximate figures. *ungefärliga siffror.*

Frequency of larvae (living):
*** = abundant; number at least equal to that of adults.
** = moderate; considerably fewer than adults.
* = occasional or few in number.
— = no larvae.

Frekvens larver (levande):
*** = talrika; antalet minst lika stort som antalet skalbaggar.
** = medelmåttig frekvens; avsevärt fåtaligare än skalbaggar.
* = fåtaliga eller enstaka.
— = inga larver.

for 19 months at 17°C, and 6½ months at ca. 13°C. An increase of temperature demonstrated that their breeding ability was not impaired by these long exposures to sub-optimal temperatures. Laboratory tests as to the resistance in adults to cold have shown that an exposure of 20 days at —2°C or 15 days at —5½ ± 1½°C is necessary before one can be certain that they are all dead.

A remarkable phenomenon occurred during the final phase of the treatment from 3 to 8 March: adults congregated in enormous numbers on the surface of the grain. They were concentrated mainly to the parts of the infested zone in which treatment had not begun, and the areas to the west as far as the wooden barrier at the outer edge of the granary, and had evidently been driven out of the hot zone during the fresh-air treatment. An obvious measure was to treat the surface layer with some suitable contact insecticide. In order to make it possible to judge the effects of cold air alone on the insects, treatment with insecticides was, however, postponed until 7 April. A pyrethrum preparation in the form of powder was mixed with the surface layer to a depth of 0.3 to 0.4 m, in a quantity corresponding to 1½ kg per ton grain, in the part of the store attacked by insects, and the rest of the surface was dusted over with ca. 1 kg per 10 sq.m. The effect of this treatment is reflected in the frequency data for 2 June and 29 July in Table 3, according to which no living insects occurred in the surface layer, and only single specimens at a depth of 0.5 m in the region of the former hot zone. A further treatment with powder was carried out in a small zone at the west edge of the store on 11 June, after it had been found that a large number of insects had survived there. The measure caused the death of practically all the insects down to a depth of 0.5 m.

Two new infested areas appeared in September round the two vertical wooden tubes mentioned above. They were in the form of pockets, rather more than 1 m deep and with a diameter of ca. 2 m. Both these pockets contained numerous specimens of *O. surinamensis*, and in one of them there were also *S. granarius*, but not in such great numbers. After treatment with two units for 5 days, the temperature had dropped from 34 to 10°C.

The removal of the grain for sale was begun in November the same year. On 1 December, while the grain in the former hot zone was being removed, 5 samples were taken for analysis of the frequency of insects. All the samples contained only isolated specimens of living, but large numbers of dead *O. surinamensis;* no larvae were found.

Condition and quality of grain. Samples for complete mill and baking analysis were taken both before and after treatment, from the infested and non-infested parts of the grain. The reports of the analyses of both samples showed that grain from the hot zone had a sour smell, which persisted in the meal, dough and bread. Such features as volume and elasticity of crumb were also impaired in the bread. In analyses of mixtures consisting of equal parts of grain from the infested zone and other parts of the store, all the negative features of the grain mentioned above remained, but not in such a high degree. The attack and the secondary effects had thus markedly reduced the quality of the grain, and the fresh-air treatment neither improved nor reduced the quality. Analyses of grain outside the infested zone showed that it was all of a normal, good quality.

Store II, wheat

This store of grain consisted of 3322 tons of Swedish spring wheat, harvested in 1958; owner SVENSK SPANNMÅLSHANDEL. It was deposited in the granary in July 1959, with a temperature of 20—22°C. The grain occupied a floor area of 40 × 28 m, and the greatest depth was 6½ m.

On 1 October 1959, when the grain had been in the granary ca. 2 months, the granary foreman reported an abnormally high temperature in large parts of the store, and that the temperature was still rising. An investigation a few days later showed that heat was developing in the whole of the wheat except for the lower parts of the short sides of the granary and the slopes of one of the long sides.

The temperatures recorded on 6 October at different points in the store are shown in the plan in Fig. 12. The highest temperatures were recorded at a depth of 0.5 to 3 m, where temperatures between 30 and 37°C where found at many points.

These high temperatures were caused by attacks of insect pests, mainly *Sitophilus oryzae* and *Rhizopertha dominica,* and, to a small extent, also *Laemophloeus ferrugineus.*

Treatment of the grain began on 13 October with six units of apparatus; another unit was added on 15 October. The work was planned to be carried out as follows.

A normal working depth of 4 m — 2 to 3 m in the slopes — was deemed to be satisfactory, with a distance of ca. 4 m between the units; this distance was found to be too great, however, and was reduced to only 2 m. Beginning in the slope in one of the short sides of the granary, the temperature of the whole store was to be reduced systematically to ca. 15°C. Close to each unit a tube fitted with thermometers at different depths was inserted into the wheat, and treatment at the respective places was to be discountinued in this first stage as soon as the temperature was down to 15°C. It was considered urgent to get the situation under control in this way as rapidly as possible, since the heat development was spread over the greater part of the grain. In renewed treatment of the whole store the aim would be to obtain the greatest possible reduction of temperature.

Eight fixed points at a depth of 2½ m were chosen for continuous daily checking of the changes of temperature during treatment. A summary of these readings will be found in Table 4, where the outside air temperature and humidity are also given.

To determine the effect of the treatment on the insects in the grain, samples were taken from depths of 1 and 2 m at 6 points in the store on 7—14 October before treatment was commenced, and at the same points on 17 February after treatment was finished; see Table 6. A series of samples from different parts of the wheat store were examined in March 1960, 5 weeks after treatment was ended, in conjunction with the removal of the wheat from the granary; see Table 7.

The water content of the wheat was measured before, during and after treatment. The results of the analyses will be found in Table 5.

Development of temperature in grain. The first phase of the treatment was finished on 23 December 1959, and it had covered the whole of the store except for a small section in the eastern part. A pause was then made in the treatment until 8 January. It was impossible to follow the plan originally drawn up, to reduce the temperature to ca. 15°C in the first phase. It is true that the temperature of the wheat had been reduced to between 10 and 18°C on the whole, but in several places the temperatures had been pressed down

	B	C	D	E	F	G	H	I	K	L	M	N	O
6 m													
8 m		13	13	15	15	15	11	15	14	12	13	12	12
10 m	14	16	15	16	18	13	17	17	16	14	15	13	13
12 m	12	12	18	18	20	22	21	25	31	16	14	16	14
14 m	15	16	17	20	20	20	22	30	26	24	15	17	15
16 m	15	17	16	20	19	19	21	30	15	32	18	18	15
18 m	16	18	17	26	25	24	30	35	29	37	37	20	17
20 m	17	17	18	31	32	31	33	25	30	35	37	25	21
22 m	15	18	20	22	33	33	33	33	33	37	37	32	26
24 m	18	22	24	23	34	35	34	35	26	36	36	34	30
						25				23			
26 m	20	18	29	25	35	34	33	34	28	36	36	34	29
										22			
28 m	23	29	32	33	34	33	30	33	27	35	36	34	28
30 m	22	28	31	31	32	32	31	32	27	34	35	33	25
32 m	21	26	29	30	27	30	27	28	25	32	29	29	25
34 m	20	24	27	25	26	28	25	25	22	29	27	26	23
36 m	18	23	27	24	25	27	25	24	20	35	24	25	21
										24			
38 m	18	21	23	22	23	24	23	24	19	18	22	22	18
					20		21						
40 m	18	20	22	22	23	23	23	23	19	23	19	19	16
42 m	15	19	20	21	22	22	22	21	17	21	16	17	16
44 m	14	16	17	19	19	18	18	17	14	16	14	15	10

NORTH END-WALL

Fig. 12. Store II. Plan of store. Temperatures in grain 6.10.1959, before treatment, at a depth of 1.5—3 m; within cirkles, 4 m.

Lager II. Planskiss av lagret. Temperaturerna i spannmålen den 6.10.1959, före behandlingen, på 1,5—3 m djup; inom ringar 4 m djup.

Table 4. Store II. Development of temperature, at a depth of 2½ metres, in 8 different parts of the wheat store.

Tabell 4. Lager II. Temperaturutvecklingen på 2½ meters djup i 8 olika delar av vetelagret.

Date *Dag*	IK-17	I-20	F-27	K-27	K-33	D-34	LM-36	F-38	Atmospheric *Ytterluftens* temp. °C.	humidity *fuktighet* %
Oct. 13.	30°	25°	31°	26°	33°	33°	24°	20°		
15.	23	24	31	24	33	33	25	20		
16.	14	35	26	36	34	33	24	25	8	95
24.	15	12	34	18	35	37	25	24	3	100
25.	15	14	19	25	35	37	27	25	9	90
26.	15	17	14	20	28	37	26	25	8	95
30.	16	14	17	18	28	34	29	26	8	96
31.	15	14	15	19	32	24	29	27	7	95
Nov. 6.	17	15	15	15	13	15	37	36	1	92
7.	15	15	15	15	13	15	13	37	0	100
9.	16	15	14	15	14	15	13	33	2	95
10.	16	15	14	16	14	15	12	9	4	70
18.	18	15	14	16	14	16	10	13	— 6	55
19.	18	16	14	16	14	17	10	9	1	100
25.	19	17	15	16	14	14	10	14	5	90
30.	16	18	15	17	15	15	10	15	3	95
Dec. 10.	9	13	15	5	8	19	6	19	— 4	94
15.	10	14	15	5	7	25	4	9	— 1	95
16.	10	13	15	5	7	10	4	10	— 2	80
20.	10	13	11	5	7	7	4	9	0	85
23.	10	13	10	5	7	19	4	13	3	
Jan. 8.	13	13	12	6	6	17	4	19		
10.	13	13	13	6	6	17	4	20		
12.	13	12	15	7	6	18	4	21	—16	96
17.	14	12	17	7	6	18	4	22	—23, —12	95
19.	3	13	17	6	6	19	4	23	—11	91
20.	3	13	18	6	6	19	4	23	—12, — 7	85
22.	3	11	19	6	6	20	4	25	—24, — 9	100
23.	3	12	19	6	6	19	4	25	0	100
25.	2	12	20	6	6	10	4	29	1	100
30.	2	12	21	6	6	9	5	5	—10, —14	86
Feb. 1.	2	11	22	7	3	9	5	12	—18, —14	90
2.	2	12	21	7	2	9	5	12	—22, —18	89
4.	3	12	18	8	1	4	5	13	— 8	84
5.	3	12	16	8	1	5	5	10	— 9	75
6.	2	12	14	8	0	3	5	9	—21, —10	90
7.	3	12	13	8	0	1	5	10	— 6	92
8.	2	12	8	8	0	—2	5	9	— 2	95
13.	2	6	4	9	0	—1	5	10	— 8	66
14.	1	4	4	9	0	—1	4	0	—25	75
15.	1	4	4	9	0	—1	5	3	— 9	95

to 2 to 4°C. It had been found during treatment that a reduction of temperature to 15°C had frequently been only temporary, and heat centres had appeared again.

This was undoubtedly due to the great frequency of heat-generating larvae of *S. oryzae* and *Rh. dominica* inside the kernels. The reduction of temperature had clearly been insufficient to produce a complete inactivity of these larvae; according to Birch, 1945, the minimum temperature for the development of larvae of *S. oryzae* is ca. 15°C, and for *Rh. dominica* ca. 18°C. The planned systematic advance of the units of equipment through the whole wheat store could not be realized owing to the necessity of eliminating new heat centres in the areas already treated. The difficulties of mastering the situation during the first phase of treatment were also increased by the unfavourable weather conditions prevailing (see Table 4), and by the fact that from 8 December onwards only 4 units were available for the continued treatment; the other 3 had to be used at another granary.

When treatment was resumed on 8 January, it was found that the temperature of the wheat had risen considerably in some parts of the store during the ca. 14 days' interval. At point E-18, for example, the temperature had risen from 11 to 33°C at 0.5 m, and at point F-20 from 18 to 35°C at the 2 m level.

Very favourable conditions for continued treatment occurred, however, with a spell of very cold weather during January and February; cf. Table 4. This made it possible during the second and final phase to eliminate the heat centres completely, both the original ones and those that appeared during the treatment. A large new hot zone had appeared within the area FH-27/34 (cf. Fig. 12) when temperatures were taken 1—2 February. There the temperature had been reduced to ca. 15°C (variations between 11 and 17°C in different parts of the area) at the turn of the month October/November 1959, but was now as high as 41°C in some spots; the frequency of insects was extremely high in places. The treatment of this zone was begun with 3 units on 12 February, and the result is worthy of special mention as an example of rapid cooling in suitable conditions. The data below refer to the temperature situation at point G-30 at a depth of 3 m.

12 Feb.	(treatment begun)	7 p.m. =	41°C
13 »		2 a.m. =	6°C
13 »		7 a.m. =	2 C

The outdoor air temperature during the treatment was ca. —10°C. Thus in twelve hours the temperature in the wheat was reduced from 41 to 2°C.

On 17 February the treatment of the whole wheat store was finished. The reduction of temperature at a depth of 2½ m between the start and immediately prior to the finish of the treatment is illustrated in the following extract from Table 4:

Point	13 oct. 1959	15 Feb. 1960
IK 17	30°C	1°C
I—20	25	4
F—27	31	4
K—27	26	9
K—33	33	0
D—34	33	—1
LM—36	24	5
F—38	20	3

Temperatures recorded on 23 March, more than a month after treatment had ended, showed that the temperature of the wheat had become stable at about the above figures for 15 February.

Water content of grain. The results of analyses of water content will be found in Table 5. During the fresh-air treatment the water content of the grain went down by 1 to 1½%, and at some points values as low as 9.5% were recorded. This was obviously a consequence of hot air, which has a very high waterbearing ability, being expelled from the grain together with its

Table 5. Store II. Water content of grain.

Tabell 5. Lager II. Spannmålens vattenhalt.

Depth *Djup*	Place; cf. Fig. 12 *Plats; jfr fig. 12*	Date of sampling *Dag för provtagning*				
		15.10.	17.12.	1.2.	8.2.	17.2.
Surface *Ytan*	I-10	12%	—	—	—	11.5%
	G-36	11.5	—	—	—	11.5
1 m	K-12	—	10.5	—	—	—
	M-18	—	10.5	—	—	—
	N-25	—	10.5	—	—	—
1.7—2 m	I-10	12	—	—	—	10.5
	M-18	—	10.5	—	—	—
	D-24	—	10	—	—	—
	G/H-27	—	—	11.5	—	—
	F/G-29	—	—	11	—	—
	H-30	—	—	11	—	—
	H/I-31	—	—	11	—	—
	G-32	—	—	12	—	—
	F-34	—	—	10	—	—
	H-34	—	—	10	—	—
	G-36	11.5	—	—	—	10
2.3—3.3 m	F/G-10	—	—	—	11	—
	I-12	—	—	—	12	—
	N-14	—	—	—	11.5	—
	D-16	—	—	—	11.5	—
	N-25	—	—	—	9.5	—
	H/I-41	—	—	—	10.5	—
3.9—4.7 m	H-16	—	—	—	12	—
	K/L-21	—	—	—	11.5	—
	E/F-22	—	—	—	11	—
	H-24	—	—	—	11	—
	K-28	—	—	—	11	—
	E-32	—	—	—	9.5	—
	M-32	—	—	—	10	—
	H-34	—	—	—	9.5	—
	L/M-38	—	—	—	10.5	—

water content. This water condensed, as in the case of similar treatments at other granaries, in the surface layer of the wheat, particularly in the vicinity of the equipment, but was eliminated without much difficulty by the methods described above — fans and fresh-air treatment of the surface layer with a separate unit. The zone round such a unit was usually dry after a couple of hours, when the equipment was moved to another position.

Effect on insects. Table 6 shows that the frequency of living insects at the close of treatment had been reduced to insignificance compared with what it had been at the beginning. Living adult insects were lacking completely, but dead ones were numerous, and emerging young adults (after the samples had been kept for 30 days at 28°C) were found only in isolated samples and only to a very small extent. The same result was obtained, as is shown in Table 7,

Table 6. Store II. Number, per kg of wheat, of insects before beginning of, and after finished treatment. – »Emerged» = young adults developed in samples of wheat kept at 28°C. for 30 days.

Tabell 6. Lager II. Antal insekter per kg vete före påbörjad och efter avslutad behandling. — »Nykläckta» = unga skalbaggar, framkomna i veteprov, som förvarades vid 28°C. i 30 dagar.

Place and depth, cf. Fig. 12 *Plats och djup, jfr fig. 12*	Before treatment, sampling 7.10.—14.10. 1959 *Före behandlingen, provtagning 7.10.—14.10. 1959*						After finished treatment; sampling 17.2. 1960 *Efter avslutad behandling; provtagning 17.2. 1960*					
	Sitoph. oryzae		Rhiz. domin.		Emerged *Nykläckta*		Sitoph. oryzae		Rhiz. domin.		Emerged *Nykläckta*	
	liv. *lev.*	dead *döda*	liv. *lev.*	dead *döda*	Sitophil. oryz.	Rhizophert. domin.	liv. *lev.*	dead *döda*	liv. *lev.*	dead *döda*	Sitophil. oryz.	Rhizophert. domin.
K-12 1 m	66	5	0	0	692	9	0	210	0	2	0	0
2 m	58	14	1	2	473	5	0	116	0	1	4	0
M-18 1 m	22	10	2	3	51	17	0	29	0	0	0	0
2 m	3	56	2	2	41	125	0	88	0	0	0	0
O-22 1 m	30	8	0	0	126	3	0	16	0	0	0	0
2 m	43	13	1	0	387	0	0	31	0	21	0	0
D-24 1 m	62	5	0	0	282	2	Sampling not performed					
2 m	19	9	1	0	200	0	*Provtagning verkställdes ej*					
I-28 1 m	8	40	0	0	8	0	0	10	0	10	0	0
2 m	4	24	9	5	14	1	0	10	0	5	0	0
G-33 1 m	3	0	0	0	0	0	0	9	0	5	0	0
2 m	8	5	0	0	0	0	0	18	0	0	5	14

in new samples taken on 24 March, in conjunction with the screening and removal of the wheat. The large numbers of dead insects in the screenings should be observed; the total amount of light corn and light screenings was ca. 67 tons.

The temperature drop in the grain to a few degrees above freezing-point, made possible by a spell of cold weather during the second treatment period, thus resulted in the death of all adult *S. oryzae* and *Rh. dominica* and practically all developmental stages within the grains of wheat. There is hardly any doubt that the fatal effect on the pests is due not only to the drop in temperature in itself, but also to its rapidity in cold weather, possibly in conjunction with simultaneous ventilation in the grain. The maximum resistance of the insects in question to cold of different degrees has been determined rather exactly experimentally. Their death in conjunction with the fresh-air treatment, however, occurred much earlier than was to be expected on the evidence of available data on resistance to cold. According to Cotton & Wagner, 1941, *S. oryzae* is capable of surviving up to 80 days at temperatures of 5 to 6°C, and up to 16 days at ca. 0°C. As regards the resistance of *Rh. dominica,* the author, 1961, has published results of tests showing that 4 to 5% of the adult insects survived in wheat exposed to outside air for 34 days, during which time the temperature of the wheat never exceeded 4°C; its average temperature was 0°C and sank for 2 days of the period to —6 to —7°C, and for 3 more days to —8°C. In laboratory experi-

Table 7. Store II. Number, per kg of wheat, of insects, 24.3.1960, 5 weeks after finished treatment. Sampling, when cleaning and removing of the grain was going on.

Tabell 7. Lager II. Antal insekter per kg vete den 24.3.1960, 5 veckor efter avslutad behandling. Provtagning i samband med pågående rensning och utlastning av spannmålen.

Place of sampling, kind of sample *Provtagningsplats, provets art*	Sitophilus oryzae		Rizopherta dominica		Young adults emerged 30 days afterwards, in samples kept at 28° *Nykläckta skalbaggar 30 dagar senare i prov, förvarade vid 28°*	
	living *levande*	dead *döda*	living *levande*	dead *döda*	S. oryzae	Rh. dominica
Before cleaning: *Före rensning:*						
K-18, various depths *varier. djup*	0	10	0	7	0	0
I-20 » »	0	44	0	11	0	0
E-24 » »	0	22	0	2	0	6
G-24 » »	0	12	0	8	0	0
H-24 » »	0	5	0	0	0	0
H-24, close to floor *invid golvet*	0	30	0	12	0	0
H-34, at 1 m depth *på 1 m djup*	0	9	0	0	0	0
H-34, at 2 m depth *på 2 m djup*	0	63	0	84	0	0
F-38, at 1 m depth *på 1 m djup*	0	0	0	0	0	0
F-38, at 2 m depth *på 2 m djup*	0	0	0	0	0	0
After cleaning: *Efter rensning:*						
Wheat, sample a) Vete, prov a)	0	5	0	3	0	0
» » b)	0	32	0	0	0	3
» » c)	0	23	0	0	0	0
Light corn *Slösäd*	0	[1]6 000	0	[1]4 000	18	92
Screenings, refuse *Rensavfall*	0	[1]14 000	0	[1]3 000	0	0

[1] *approximate figures.*
ungefärliga siffror.

ments, also reported by the author in the abovementioned work, ca. 30% of adult *Rh. dominica* survived 10 days' exposure to a constant temperature of −1½°C. As shown in Table 4 of the present paper, the drop in temperature in great parts of the wheat store was never so great that it could alone be expected to cause the high mortality in the insects.

Condition and quality of grain. Samples of the wheat were taken for analysis of condition, and complete milling analyses were made on October 15 in conjunction with the commencement of treatment. The analyses showed that the quality of the wheat was not impaired.

It was decided, however, to sell the wheat as soon as marketing conditions were favourable, and it was removed from the granary in March 1960. After screening, the wheat was delivered to mills in prime condition, which surely could not have been done without the fresh-air treatment which cooled the grain and eliminated the insect pests.

Comments. Cost of treatment. The initial conditions were unfavourable in that practically the whole of the large wheat store was affected. Further, the weather was relatively mild right up to January. The work was therefore very time consuming, particularly as the number of units of equipment was reduced from 7 to 4 after a time, and lasted for almost 3½ months, excluding the interval around the turn of the year. The result, however, must be considered very satisfactory, both regarding the cooling of the grain and the maintenance of its good condition and the elimination of insect pests.

The total cost of the treatment was 23,403 kronor, which is equivalent to 0.7 öre per kg wheat.

Summary

Mobile equipment for the airing and cooling of grain stored in bulk, and the consequent elimination of insect pests, has been used on a large scale in Sweden during recent years.

The equipment consists roughly of a thick (diameter 102 mm) steel tube in sections, the lowest section being pointed and perforated, a machine for driving the tube into and withdrawing it from the grain, and an electric fan to force fresh air into the tube and, through the perforations, into the grain; Figs. 2—5. The treatment was carried out at a depth of down to 5—6 m in the grain. For less extensive treatment at working depths of down to ca. 3 m, a type of apparatus, constructed for manual insertion and extraction of a tube with a thread at the lower end and a wheel adjustable along the tube was also used; Fig. 1.

The present paper reports the treatment of two different stores of grain, one of rye (Store I) and the other of wheat (Store II). The most important findings in these treatments can be summarized in the following points:

1. Treatment in cold weather brings about rapid cooling of grain in which insect pests have caused a rise of temperature, with consequent elimination of all pests sensitive to cold. This fatal effect is apparently due not only to the drop in temperature itself, but also to the rapidity of the drop, and possibly also to the strong ventilation of the grain.

2. Results at Store I show that the treatment can be effective even under unfavourable weather conditions. Although reductions of temperature in such cases are not great enough to kill adult insects, they can lead to complete and lasting stagnation in all developmental stages, whereby further damage to the grain and generation of heat are prevented. Experience gained in the first phase of treatment at Store II suggest that efforts should be made right from the beginning to reduce the temperature of the grain as far as weather conditions permit. In this way it is possible to check completely the activity of insect pests and prevent renewed generation of heat in the part of the grain store already treated.

3. Not even under unfavourable conditions regarding the humidity of the outside atmosphere was there any increase in the water content of the grain in the hot zones. When the fresh

air is dry, the grain is dried considerably. Condensation in the surface layer of the grain appears regularly in conjunction with treatment by the method described here. For that reason, rapid ventilation of the granary is necessary during treatment. The condensation water in the surface layer can be removed rapidly with the help of fans, and by airing the upper layers of the grain with equipment working at shallow depths.

4. In some cases the treatment causes the insects to move up to the surface of the grain, where they can easily be exterminated by contact insecticides.

Sammanfattning

Flyttbara apparater för luftgenomblåsning och i samband därmed kylning av insektsangripen och varm, löst lagrad spannmål har på senare år använts i stor skala i Sverige.

Konstruktionen består i korthet av ett grovt (diam. 102 mm), i hopkopplingsbara sektioner indelat stålrör, med den nedersta sektionen tillspetsad och perforerad, vidare en maskinell anordning för rörets neddrivande i och uppdragande ur spannmålen, samt en elektrisk fläkt för intryckning av friskluft i röret och via perforeringarna in i spannmålen; fig. 2—5. Behandlingar har utförts på ett djup i spannmålen av ned till 5—6 meter. För mindre omfattande behandlingar och vid ett arbetsdjup av ned till ca 3 meter har även använts en apparattyp, konstruerad för manuell ned- och uppskruvning av ett rör med hjälp av en i dess nedre del monterad skruvgänga och en utefter röret flyttbar ratt; fig. 1.

I föreliggande arbete har redogjorts för behandlingar av två olika spannmålslager, det ena omfattande råg (Lager I), det andra vete (Lager II). De viktigaste erfarenheterna i samband med dessa behandlingar kan sammanfattas i följande punkter.

1. Behandling vid kall väderlek åstadkommer en snabb nedkylning av en till följd av insektsangrepp varm spannmålsmassa och har därjämte dödande verkan på åtminstone mera värmekrävande former av skadedjur i alla utvecklingsstadier. Denna dödande verkan sammanhänger uppenbarligen ej blott med den åstadkomna temperatursänkningen som sådan, utan även med nedkylningens chockartat snabba förlopp från höga till låga temperaturvärden samt eventuellt även med den starka luftväxlingen i spannmålen.

2. Resultaten från Lager I visar, att behandling kan ge god effekt även vid mindre gynnsamma väderleksbetingelser. Även om temperatursänkningen i sådana fall ej blir tillräcklig för dödande verkan på befintliga skadedjur, kan densamma dock åstadkomma en mer eller mindre fullständig och stadigvarande stagnation i deras fortplantning och i utvecklingsstadiernas vidareutveckling, varigenom fortsatt skadegörelse i varan jämte värmeutveckling förhindras. Erfarenheterna från första behandlingsomgången i Lager II tyder på att man redan från behandlingens begynnande bör nedbringa varans temperatur till så låg nivå som väderleksbetingelserna medger. Därigenom kan det bli möjligt att mera fullständigt hämma befintliga skadedjurs aktivitet och motverka uppkomst av förnyad värmeutveckling i redan behandlade delar av lagret.

3. Behandling har ej ens vid ogynnsamma betingelser med avseende på friskluftens fuktighetshalt åstadkommit någon stegring av vattenhalten hos spannmålen i värmehärdarna. När friskluften är någorlunda torr, sker en påtaglig uttorkning av spannmålen. Kondensering av fuktighet i spannmålens ytskikt är ett regelbundet uppträdande fenomen i samband med behandling enligt ifrågavarande metod. Av den anledningen är en kraftig luftväxling i lagerlokalen städse nödvändig under behandlingens fortgång. Kondensvattnet i

ytskiktet elimineras snabbt med hjälp av luftfläktar samt genom luftning av spannmålens ytligare lager medelst för ändamålet avdelade apparater, inställda på ett ringa arbetsdjup.

4. I vissa fall åstadkommer behandlingen att insekterna i stora mängder förflyttar sig från det inre av spannmålsmassan upp till ytan. De blir där lätt åtkomliga för bekämpning med kontaktverkande insekticider.

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